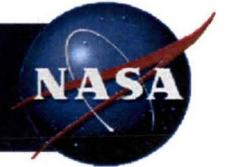


# TFAWS Aerothermal Paper Session



## An Upgrade of the Aeroheating Software “MINIVER”

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# Introduction



- Background
  - Detailed computational modeling
    - CFD often used to create and execute computational domains
    - Increasing complexity when moving from 2D to 3D geometries
    - Computational time increased as finer grids are used (accuracy)
    - Strong tool, but takes time to set up and run
  - MINIVER
    - Uses theoretical and empirical correlations
    - Orders of magnitude faster to set up and run
    - Not as accurate as CFD, but gives reasonable estimations
- MINIVER's Drawbacks
  - Rigid command-line interface
  - Lackluster, unorganized documentation
  - No central control; multiple versions exist and have diverged





# MINIVER Conversion: Background



- **Special Study**
  - Initiated by NASA KSC's Launch Services Program
  - Managed by a.i. solutions
  - Initially performed by Florida Institute of Technology
- **First Development Phase**
  - Written in C# (C-Sharp)
  - Updated user interface
  - Addition of helpful tools
  - Inclusion of basic CAD geometry editor
- **MINIVER Version**
  - Based on the 1983 upgrade by Engel, Praharaj, and Schmitz<sup>1,2</sup>
  - Code comments indicate upgrades in 2000, 2003
  - PREMIN and LANMIN upgraded, EXITS not carried over



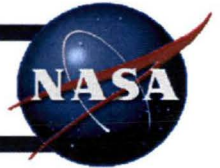
# MINIVER Conversion: PREMIN Module



- PREMIN Prompts
  - Whether to use English or Metric units for data input
  - What time intervals to use for data printout
  - Vehicle trajectory; manual input or file import
  - Which atmosphere model to use
  - Which heat transfer model to use
  - How to consider flow transition
  - Whether to consider crossflow or not
  - What type of flowfield and pressure environment to consider
  - If the surface geometry changes over time
  - How the wall temperature should be determined
  - How the user wants the output file to be generated



# MINIVER Conversion: PREMIN Module



```
trajectory input is complete

      atmosphere data

options  1. 1962 u.s. standard atmosphere
         2. wind tunnel option
         3. input atmospheric data<alt,t-inf,p-inf>
         4. 1963 patrick air force base atmosphere
         5. 1971 vandenberg reference atmosphere
         6. 1973 vandenberg hot day atmosphere
         7. 1973 vandenberg cold day atmosphere
         8. 1971 kennedy hot day atmosphere
         9. 1971 kennedy cold day atmosphere
        10. 1976 u.s. standard atmosphere

option selected ?
10

1976 u.s. standard atmosphere

is this option correct ?
y

do you want to run a heating indicator ?
n

      heat transfer method

options  1. hemisphere stagnation point
         2. cato/johnson swept cylinder
         3. eckert ref. enthalpy flat plate method
         4. eckert/spaulding-chi flat plate method
         5. boeing rho-mu flat plate method
         6. beckwith/gallagher swept cylinder method
         7. boeing rho-mu swept cylinder method
         8. lees/detra-hidalgo hemisphere distribution
         9. leeside orbiter heating
        10. flap reattachment heating
        11. fin-plate peak interference heating
        12. brake payload impingement heating
```

Sample screenshot: Legacy PREMIN menu

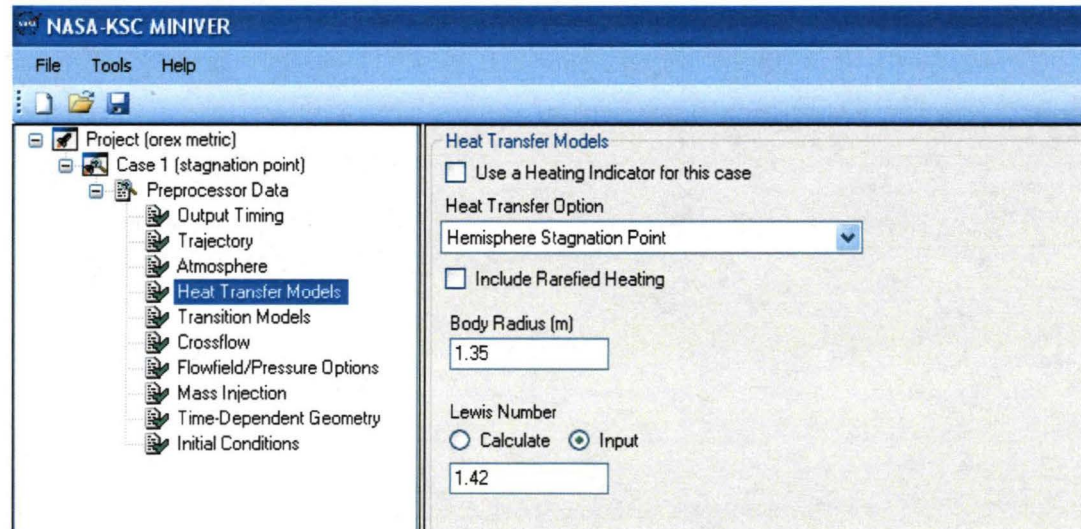




# MINIVER Conversion: PREMIN Module



- New User Interface
  - PREMIN prompts collapsed into MINIVER 2.0 categories
  - Analysis revolves around a “Project” (e.g. launch vehicle)
  - Projects include “Cases” (e.g. body points)
  - Each case has preprocessor data that defines it



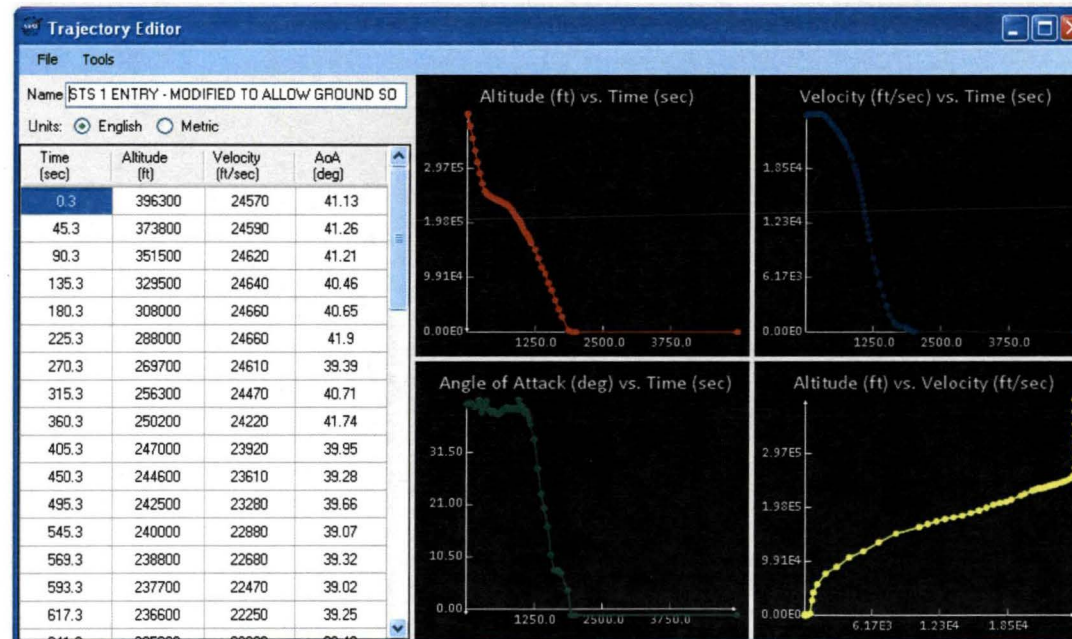
MINIVER 2.0 Main Screen



# MINIVER Upgrades: Trajectory Editor



- New Tool: Trajectory Editor
  - Allows user to visualize trajectories
  - Runs within MINIVER or as a standalone program
  - New, open, edit, and save capabilities
  - Can import via Legacy format or custom delimited text files



Trajectory Editor

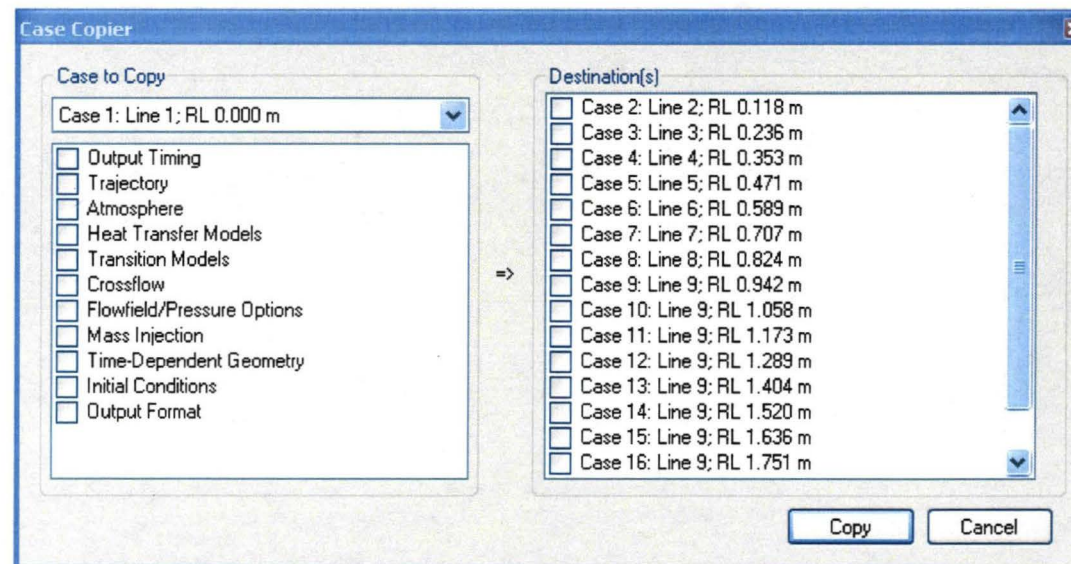




# MINIVER Upgrades: Case Copier



- New Tool: Case Copier
  - Allows quick copy from one case to many
  - Can start new cases with copied data
  - Useful for cases that share common data (e.g. trajectories)



Case Copier



# MINIVER Upgrades: Delimited File Importer



- New Tool: Delimited File Importer
  - Allows most text files to have data imported
  - Utilizes single character or whitespace for delimiting
  - Reusable code within MINIVER; constructor varies the output

CAD Import: Delimited File

File Path  
C:\Documents and Settings\Pierce\Desktop\vorexgeometry\_e Browse...

Custom Delimiter: , ☐ Use Whitespace as Delimiter Try Import

Start X	Start Y	End X	End Y
0	0	0.016854192	0.386024463
0.016854192	0.386024463	0.067288498	0.769111048
0.067288498	0.769111048	0.150919081	1.146344233
0.150919081	1.146344233	0.267109464	1.514853046
0.267109464	1.514853046	0.414975366	1.871832912
0.414975366	1.871832912	0.593391439	2.214567
0.593391439	2.214567	0.800999829	2.540446896
0.800999829	2.540446896	1.036220512	2.846992457
1.036220512	2.846992457	3.23	5.461
3.23	5.461	4.42913	0.986
4.42913	0.986	4.94751	0.46762

OK Cancel

Delimited File Importer





# MINIVER Conversion: LANMIN Module



- Code Conversion
  - Code initially left the same
  - Most conversion efforts involved replacing constructs like “go to”
  - LANMIN module is now a library within MINIVER 2.0
  - Processor logic can be executed case-by-case or project-wide

Case Output Setup [Stagnation Point]

Ready for run.  
Output Units: ☐ English ☒ Metric

☒ Generate Summary Output

Summary Output

☒ Generate Excel Output

Output Variable	Graph?
Altitude	<input checked="" type="checkbox"/>
Velocity	<input checked="" type="checkbox"/>
Mach Number	<input checked="" type="checkbox"/>
Angle of Attack	<input checked="" type="checkbox"/>
Reynolds # Per Length	<input checked="" type="checkbox"/>
Heat Coefficient	<input checked="" type="checkbox"/>
Recovery Enthalpy	<input checked="" type="checkbox"/>
Radiation Equilibrium	<input checked="" type="checkbox"/>
Heat Rate	<input checked="" type="checkbox"/>
Heat Load	<input checked="" type="checkbox"/>
Pressure	<input checked="" type="checkbox"/>

☐ Generate Detailed Output

Single case processor setup

Project Properties

Project Name: OREX Test

Project Path: D:\Users\plouderb\Desktop\Latest Release\E

Project Input Units: Metric

Run	Case Name	Summary	Excel	Detailed	Status
<input checked="" type="checkbox"/>	Stagnation Point	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Ready
<input checked="" type="checkbox"/>	CC Nose Cap - RL 0.118 m	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Ready
<input checked="" type="checkbox"/>	CC Nose Cap - RL 0.236 m	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Ready
<input checked="" type="checkbox"/>	CC Nose Cap - RL 0.353 m	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Ready
<input checked="" type="checkbox"/>	CC Nose Cap - RL 0.471 m	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Ready
<input checked="" type="checkbox"/>	CC Nose Cap - RL 0.589 m	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Ready
<input checked="" type="checkbox"/>	CC Nose Cap - RL 0.707 m	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Ready
<input checked="" type="checkbox"/>	CC Nose Cap - RL 0.824 m	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Ready
<input checked="" type="checkbox"/>	Silica Rings - RL 0.942 m	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Ready
<input checked="" type="checkbox"/>	Silica Rings - RL 1.058 m	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Ready
<input checked="" type="checkbox"/>	Silica Rings - RL 1.173 m	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Ready
<input checked="" type="checkbox"/>	Silica Rings - RL 1.289 m	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Ready
<input checked="" type="checkbox"/>	Silica Rings - RL 1.404 m	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Ready

☒ Generate Global Comparison

X-Axis: Time

Y-Axis: Heat Load

Project-wide case processor setup

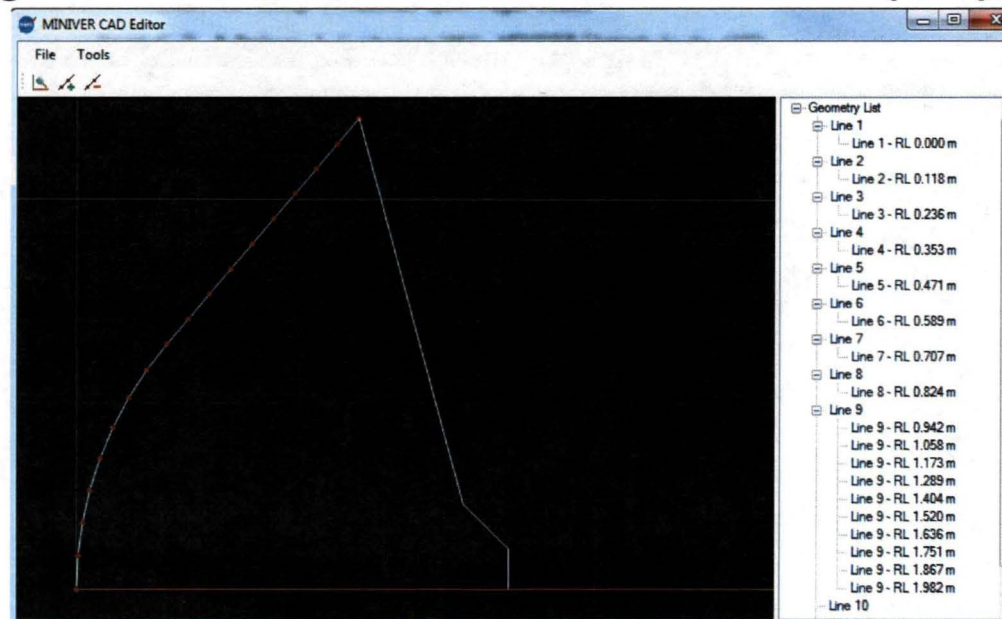




# MINIVER Upgrades: CAD Editor



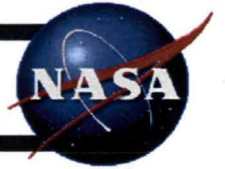
- New Tool: CAD Editor
  - Imports basic 2D geometries from AutoCAD or delimited text
  - Points can be generated on lines to create MINIVER cases
  - Cumulative running lengths and local geometric angles are automatically calculated
  - Rectangular box select available to edit multiple points at once



CAD Editor example with OREX geometry<sup>3</sup>



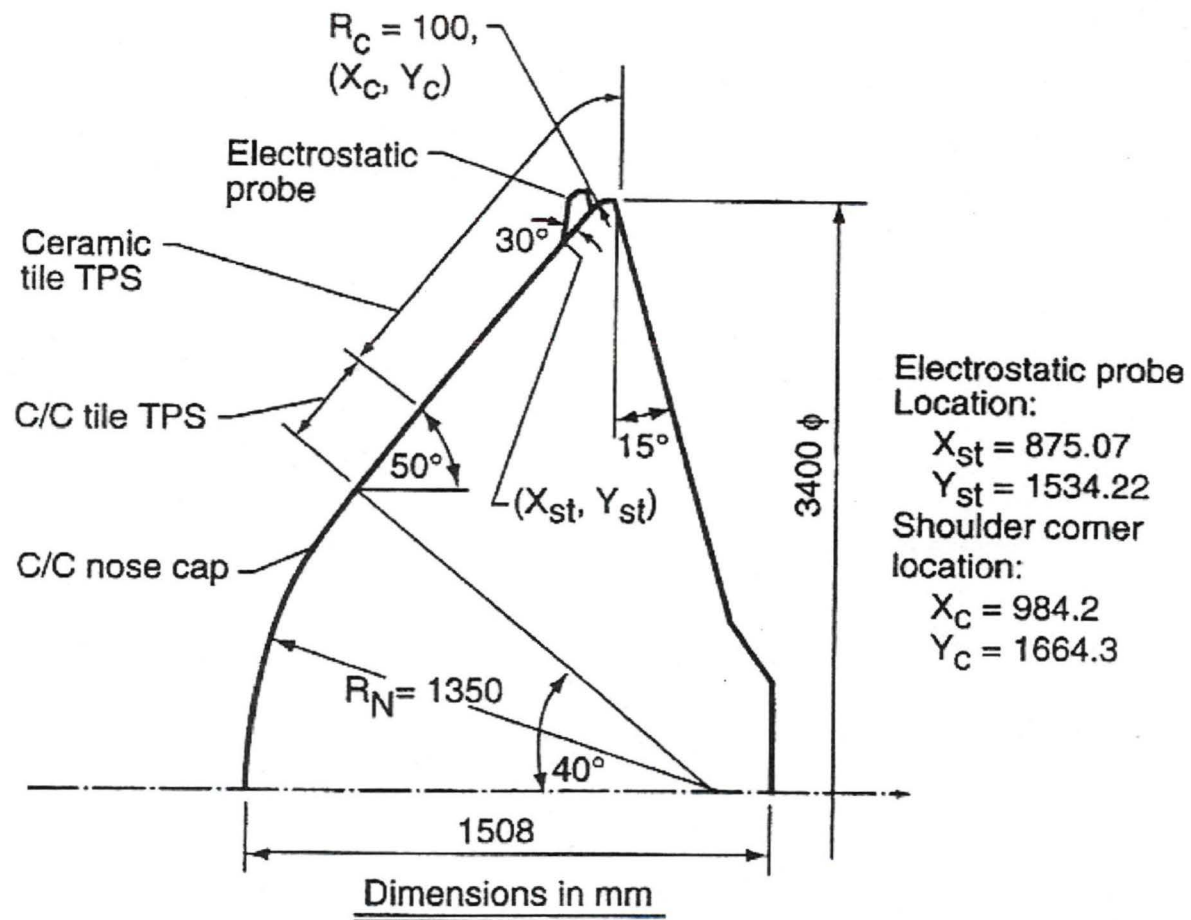
# OREX Test Setup



- Data from Gupta, Moss, and Price's paper<sup>3</sup>
- Flight data used for small subset of re-entry period
  - Trajectory
  - Geometry
  - Flight conditions
    - 1962 U.S. Standard Atmosphere approximation
    - Hemisphere Stagnation Point option at stagnation point
    - Lees/Detra/Hidalgo Hemisphere option on the spherical nose cap
    - Eckert Reference Enthalpy Flat Plate for the rest of the forebody
      - Mangler transformations used to convert from flat plate to cone
- Experimental data was only taken at stagnation point



# OREX Geometry



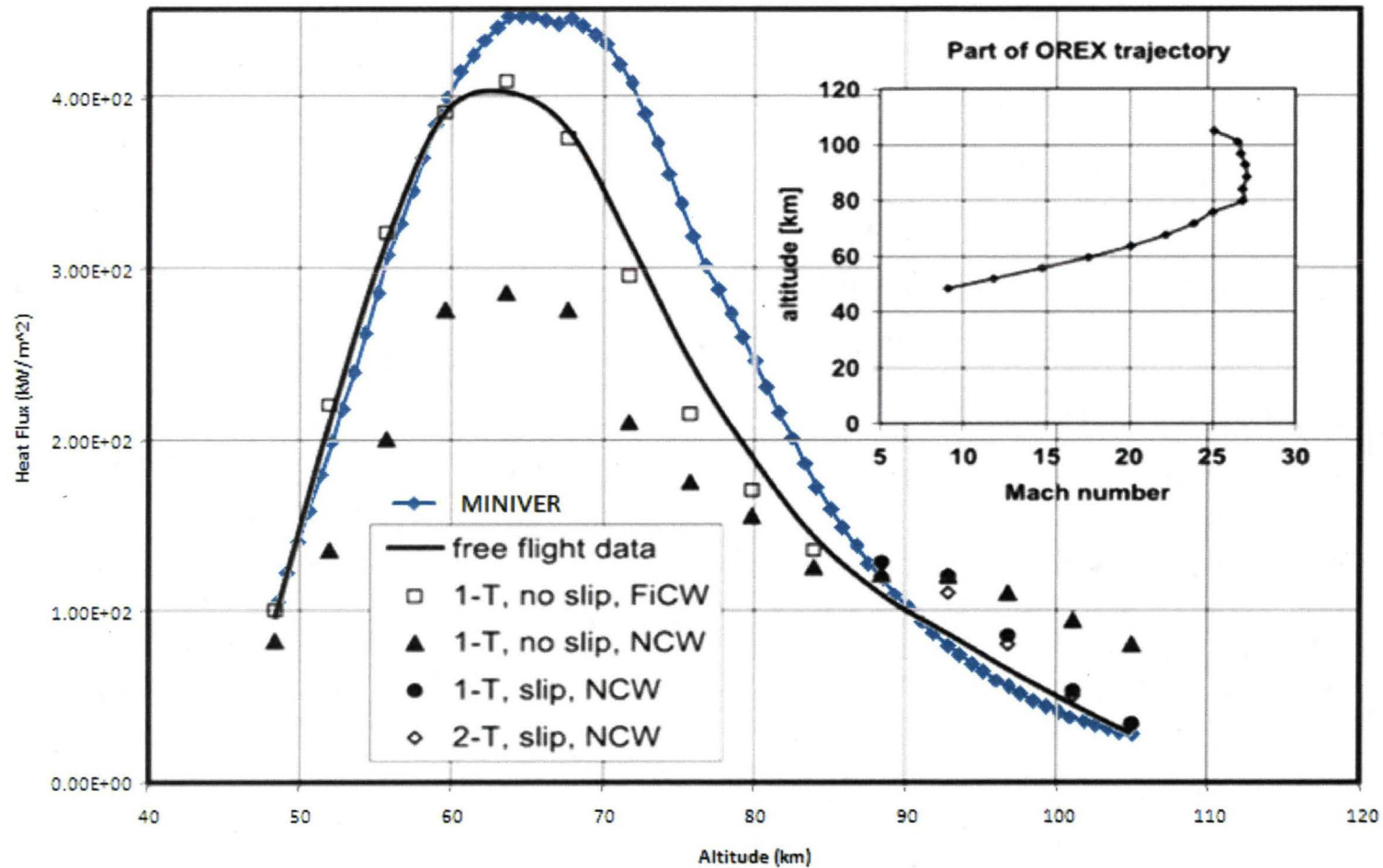




# OREX Results

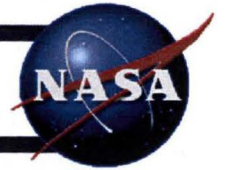


## OREX Stagnation Point Flight Data Comparison (plot overlay via Hirschel & Weiland)<sup>4</sup>

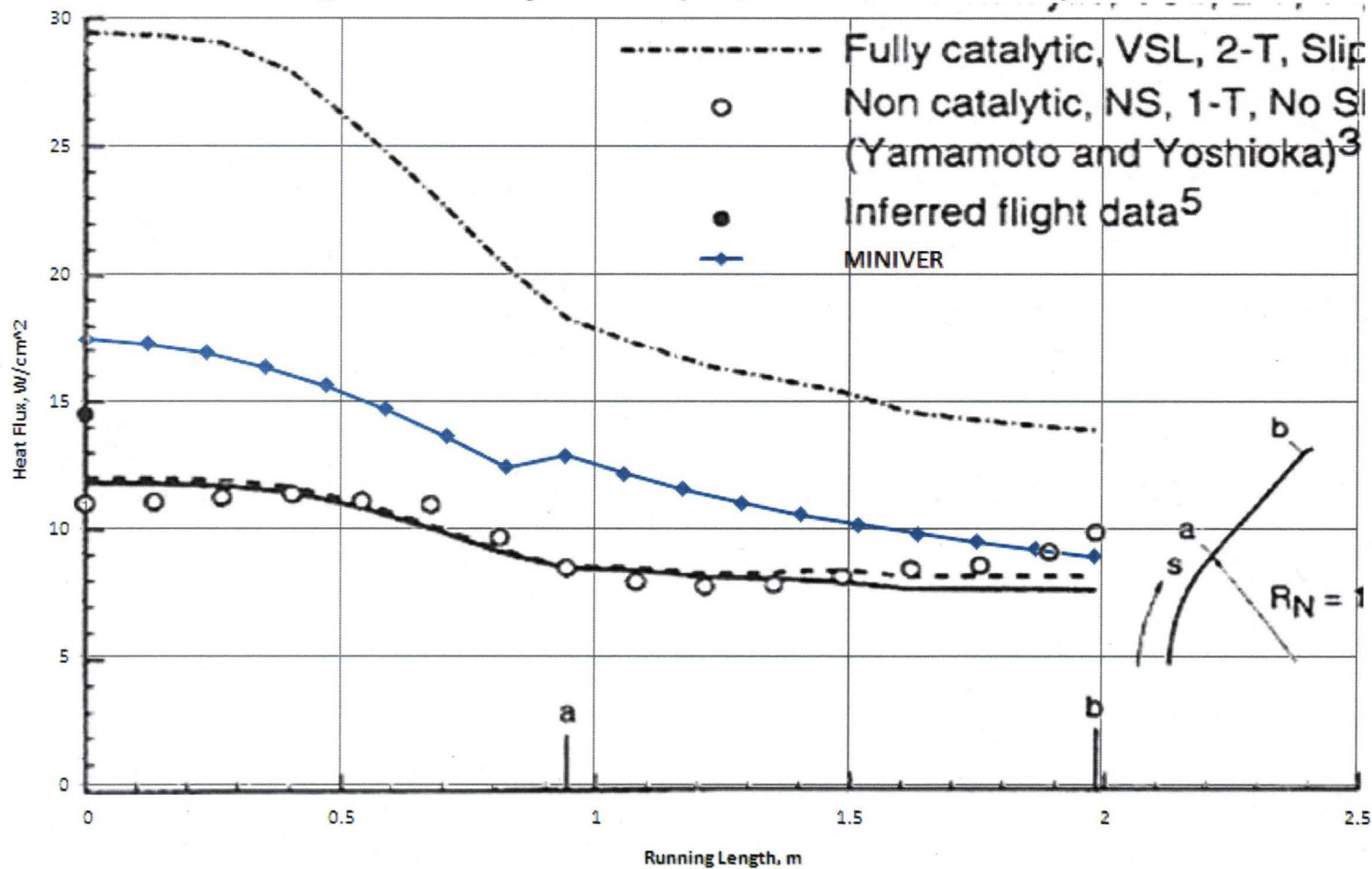




# OREX Results



OREX forebody heat rate at 84.01 km; MINIVER comparison to VSL calculations  
(plot overlay via Gupta, Moss, and Price)<sup>3</sup>

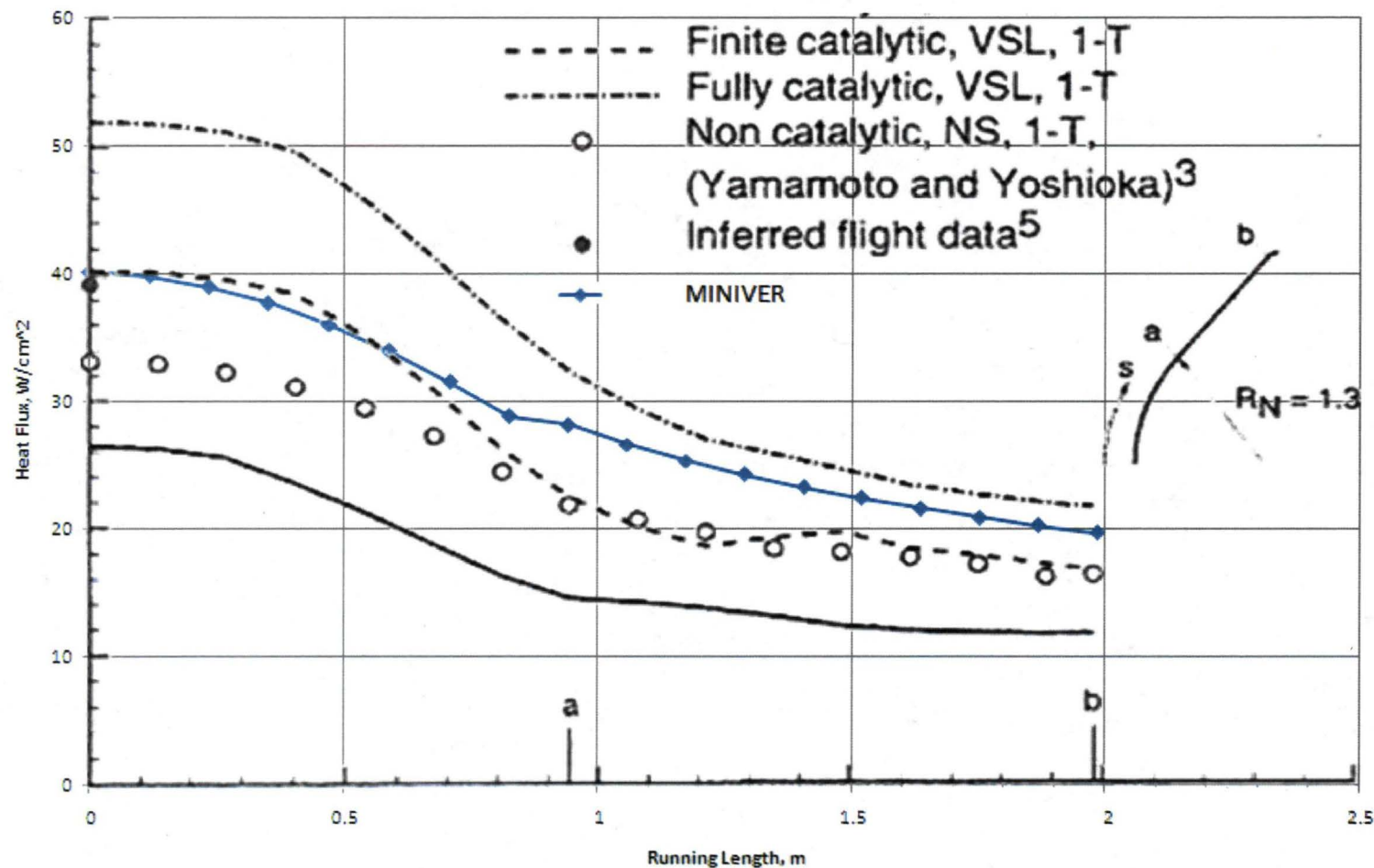




# OREX Results



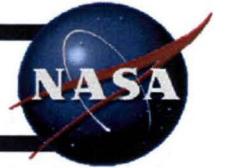
OREX forebody heat rate at 59.60 km; MINIVER comparison to VSL calculations  
(plot overlay via Gupta, Moss, and Price)<sup>3</sup>







## Conclusions and Future Work



- MINIVER updates are an ongoing effort
  - New interface provides fast, intuitive workflows for users
  - Added utilities assist in performing setup tasks
  - Results demonstrate effectiveness for fast estimation
  - MINIVER is source controlled and developed at KSC
- Future Work
  - Next phase will explore links to SINDA and Thermal Desktop
  - New features will be added based on user need
  - Would like to explore converging MINIVER from other centers
  - Experimenting with third party and open source libraries to improve the MINIVER's look, feel, and capabilities



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<sup>b</sup> Associate Department Head, Associate Professor, Mechanical & Aerospace Engineering, Florida Institute of Technology

<sup>c</sup> Associate Professor, Mechanical & Aerospace Engineering, Florida Institute of Technology



**Questions?**





## References



1. Engel, C.D., and Praharaj, S.C. (August 1983). *MINIVER Upgrade for the AVID System, Vol 1: LANMIN User's Manual*. NASA CR-172212.
2. Engel, C.D., and Schmitz, C.P. (August 1983). *MINIVER Upgrade for the AVID System, Vol 2: LANMIN Input Guide*. NASA CR-172213.
3. Gupta, R.N., Moss, J.N., and Price, J.M. (1997). Assessment of Thermochemical Nonequilibrium and Slip Effects for Orbital Re-Entry Experiment. *Journal of Thermophysics and Heat Transfer*, 11(4)
4. Hirschel, E. H., and Weiland, C. *Selected Aerothermodynamic Design Problems of Hypersonic Flight Vehicles*.



## **Backup Slides**



# Modern Summary



- Provides summary of all case data set so far

Preprocessor Data	
Modern Summary (Verbose Format) ▼	
Data Entry	Data Value
<b>Output Timing</b>	
Time 0	0
Delta Time 0	5
Time 1	100
Delta Time 1	100
Time 2	1000
Delta Time 2	0
Time 3	0
<b>Trajectory</b>	
Trajectory Name	STS 1 ENTRY - MODIFIED TO ALLOW GROUND SOAKBACK TIME
Trajectory Data Point 1	Time: 0.1, Altitude: 396300, Velocity: 24570, Angle of Attack: 41.13
Trajectory Data Point 2	Time: 45.3, Altitude: 373800, Velocity: 24590, Angle of Attack: 41.26
Trajectory Data Point 3	Time: 90.3, Altitude: 351500, Velocity: 24620, Angle of Attack: 41.21





# Preprocessor Summary



- Provides Legacy (W Array) summary of all data entered

Preprocessor Data

Legacy Summary (W Array Format) ▼

W Array Index	W Array Value
w[1]	0
w[2]	5
w[3]	100
w[4]	100
w[5]	1000
w[6]	0
w[7]	0
w[8]	0
w[9]	0
w[10]	0
w[11]	0
w[12]	0
w[13]	0
w[14]	0
w[15]	0
w[16]	0
w[17]	0
w[18]	0
w[19]	0
w[20]	0



# Heat Transfer Model Example



## Heat Transfer Models

☐ Use a Heating Indicator for this case

### Heat Transfer Option

Eckert / Spaulding-Chi Flat Plate

Running Length (ft)

20.000

Laminar Mangler Factor

3

Turbulent Mangler Factor

2

Surface Distance to Turbulent BL (ft)

0

☐ Use Automatic Virtual Origin Correction

Option disabled due to flow transition choice.

Reynolds Analogy Factor

☒ Colburn ☐ Von Karman

☒ Include Rarefied Heating

Blunt Cone



# Crossflow Option Example



Crossflow

Crossflow Option

Constant Width Rectangle (Real Gas)



Rectangle Width (ft)

Edge Radius (ft)

Real Gas Velocity Gradient

0.31 for flat surface, 1.0 for swept cylinder.





# Mass Injection Option Example



Mass Injection

Mass Injection Option

Blowing [Calculated Mass Flux] ▼

Coolant Molecular Weight (lbm/lbmol)

Porous Media Thickness (ft)

Viscous Resistance Coefficient (ft<sup>-2</sup>)

Internal Pressure (lbf/ft<sup>2</sup>)

Initial Resistance Coefficient (ft<sup>-1</sup>)

Delta Pressure across Porous Media (lbf/ft<sup>2</sup>)

Coolant Temperature (R)  
Set to 0.0 to use wall temp.



# CAD Editor Point Adding



**Add Points to Line** [X]

Selected Line: Line 1

Line Length: 0.12

Number of Points:

Grading Method: Evenly Spaced [v]

Ratio:

☐ Use Geometry Angle for Flowfield Properties